Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

By JAMES A. MILLER

REGIONAL AQUIFER-SYSTEM ANALYSIS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1403–B

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1986

GEOLOGY

REGIONAL SETTING

The Coastal Plain province of the Southeastern United States is underlain by a thick sequence of unconsolidated to semiconsolidated sedimentary rocks that range in age from Jurassic to Holocene. These sediments thicken seaward in the study area from a featheredge where they crop out against older metamorphic and igneous rocks of the Piedmont and Applachian provinces to a maximum penetrated thickness of more than 21,100 ft in Mobile County in southern Alabama. In southern Florida, the thickness of Coastal Plain sediments probably exceeds 25,000 ft; however, the maximum thickness penetrated there as of this writing (1984) is slightly more than 18,600 ft. Coastal Plain rocks generally dip gently toward the Atlantic Ocean or the Gulf of Mexico, except where they are warped or faulted on a local to subregional

Table 1.—*Microfauna characteristic of the several chronostratigraphic units in the study area, and their cross-section designations*

Cross-section designation	Fossil
	Miocene Series
M-1	*Amphistegina chipolensis* Cushman and Ponton
M-2	*Amphistegina lessoni* d'Orbigny
M-3	*Bolivina floridana* Cushman
M-4	*Bolivina marginata multicostata* Cushman
M-5	*Elphidium chipolensis* (Cushman)
M-6	*Sorites* sp.
M-7	*Aurila conradi* (Howe and McGuirt)
M-8	*Hemicythere amygdula* Stephenson
	Oligocene Series
OL-1	*Pararotalia byramensis* Cushman
OL-2	*Miogypsina* sp.
OL-3	*Pulvinulina mariannensis* Cushman
OL-4	*Robulus vicksburgensis* (Cushman) Ellisor
OL-5	*Palmula caelata* (Cushman) Israelsky
OL-6	*Globigerina selli* (Borsetti)
OL-7	*Lepidocyclina leonensis* Cole
OL-8	*Lepidocyclina parvula* Cole
OL-9	*Aurila kniffeni* (Howe and Law)
OL-10	*Pararotalia mexicana mecatepecensis* Nuttall
	Eocene Series
Late Eocene:	
UE-1	*Bulimina jacksonensis* Cushman
UE-2	*Robulus gutticostatus* (Gumbel) var. *cocoaensis* (Cushman)
UE-3	*Amphistegina pinarensis* Cushman and Bermudez var. *cosdeni* Applin and Jordan
UE-4	*Lepidocyclina ocalana* Cushman
UE-5	*Lepidocyclina ocalana floridana* Cushman
UE-6	*Eponides jacksonensis* (Cushman and Applin)
UE-7	*Gyroidina crystalriverensis* Puri
UE-8	*Globigerina tripartita* Koch
UE-9	*Operculina mariannensis* Vaughn
UE-10	*Cytheretta alexanderi* Howe and Chambers
UE-11	*Clithocytheridea caldwellensis* (Howe and Chambers)
UE-12	*Clithocytheridea garretti* (Howe and Chambers)
UE-13	*Jugosocythereis bicarinata* (Swain)
UE-14	*Haplocytheridea montgomeryensis* (Howe and Chambers)
UE-15	*Asterocyclina* sp.

scale. Coastal Plain sediments were laid down on an eroded surface developed on igneous intrusive rocks, low-grade metamorphic rocks, mildly metamorphosed Paleozoic sedimentary rocks, and graben-fill sedimentary deposits of Triassic to Early Jurassic age (Barnett, 1975; Neathery and Thomas, 1975; Chowns and Williams, 1983). Because rocks older than Early Jurassic lie at great depths, their relations and configurations are not as well known as those of the shallower Coastal Plain rocks.

The poorly consolidated Coastal Plain sediments are easily eroded. The carbonate rocks are dissolved by downward-percolating water, the result being the formation of karst topography where such rocks are at or near the surface. Accordingly, the topography developed in much of the study area is characterized by (1) extensive, slightly dissected plains, (2) low, rolling hills, and (3)widely spaced drainage. Local to subregional sinkhole topography is present where limestone rocks lie at or near land surface. A series of

Middle Eocene:	
ME-1	*Asterigerina texana* (Stadnichenco)
ME-2	*Dictyoconus* sp.[1]
ME-3	*Spirolina coreyensis* (Cole)
ME-4	*Lituonella floridana* (Cole)
ME-5	*Discorbis inornatus* Cole
ME-6	*Valvulina cushmani* Applin and Jordan
ME-7	*Valvulina martii* Cushman and Bermudez
ME-8	*Discorinopsis gunteri*[1] Cole
ME-9	*Fabularia vaughani* Cole and Ponton
ME-10	*Textularia coreyensis* Cole
ME-11	*Gunteria floridana* Cushman and Ponton
ME-12	*Pseudorbitolina cubensis* Cushman and Bermudez
ME-13	*Globorotalia bullbrooki* Bolli
ME-14	*Amphistegina lopeztrigoni* Palmer
ME-15	*Ceratobulimina stellata* Bandy
ME-16	*Globorotalia spinulosa* Cushman[2]
ME-17	*Clypeina infundibuliformia* Morellet and Morellet (alga)
ME-18	*Leguminocythereis petersoni* Swain
ME-19	*Lepidocyclina antillea* Cushman (=*L. gardnerae* Cole)
Early Eocene:	
LE-1	*Miscellanea nassauensis* Applin and Jordan
LE-2	*Helicostegina gyralis* Barker and Grimsdale[3]
LE-3	*Lockhartia* sp.
LE-4	*Globorotalia formosa gracilis* Bolli
LE-5	*Globorotalia subbotinae* Morozova
LE-6	*Globorotalia wilcoxensis* (Cushman and Ponton)
LE-7	*Pararotalia trochoidiformis* (Lamarck)
LE-8	*Brachycythere jessupensis* Howe and Garrett
LE-9	*Haplocytheridea sabinensis* (Howe and Garrett)
LE-10	*Pseudophragmina (Proporocyclina) cedarkeyensis* Cole
Paleocene Series	
P-1	*Globorotalia pseudomenardii* Bolli
P-2	*Borelis floridanus* Cole
P-3	*Borelis gunteri* Cole
P-4	*Valvulammina nassauensis* Applin and Jordan
P-5	*Globorotalia angulata* (White)
P-6	*Globorotalia pseudobulloides* (Plummer)
P-7	*Cythereis reticulodacyi* Swain
P-8	*Krithe perattica* Alexander
P-9	*Trachylebris prestwichiana* (Jones and Sherborn)
P-10	*Globorotalia velascoensis* (Cushman)

[1] Locally these species may also occur in rocks of Oligocene age.
[2] Occurs locally in rocks of late early Eocene age.
[3] Occurs locally in the lower part of the middle Eocene.

sandy marine terraces of Pleistocene age has been developed in much of the area. Stringfield (1966) has discussed the physiography of the study area in detail.

Coastal Plain sediments in the project area can be separated into two general facies: (1) predominantly clastic rocks containing minor amounts of limestone that extend southward and eastward toward the Atlantic Ocean and the Gulf of Mexico from the Fall Line that marks the inland limit of the Coastal Plain and (2) a thick, continuous sequence of shallow-water platform carbonate rocks that underlie southeastern Georgia and all of the Florida peninsula. In north-central Florida and in southeastern Georgia, where these clastic and carbonate rocks generally interfinger with one another, facies changes are both rapid and complex. In general, the limestone facies of successively younger units extends progressively farther and farther updip and encroaches to the northwest upon the clastic rocks in an onlap relation, at least until the end of Oligocene time. Miocene and younger rocks comprise a clastic facies that, except where it has been removed by erosion, covers the older carbonate rocks everywhere. The various stratigraphic units within both the clastic- and the carbonate-rock areas are separated by unconformities that represent breaks in sedimentation. As in most regional studies, however, these unconformities are not synchronous surfaces that extend throughout the project area.

Cretaceous rocks generally crop out in a band adjacent to the crystalline rocks and folded strata of the Piedmont and Appalachian provinces. In northeastern Georgia, Eocene and Miocene sediments cover rocks of Cretaceous age in an overlap relation. Figure 2 is a generalized geologic map showing the distribution of rocks of various ages in and adjacent to the project area. Rocks of Tertiary age, whose carbonate facies comprise most of the Floridan aquifer system, crop out in a discontinuous band seaward of the Cretaceous sediments and are also exposed in an area in western peninsular Florida. Still farther seaward, a band of predominantly clastic rocks of Miocene age crops out to form the upper confining unit of the Floridan aquifer system. Miocene rocks generally separate the Floridan from Pliocene and Quaternary strata that are mostly sands and comprise a surficial (unconfined) aquifer.

RELATION OF STRATIGRAPHIC AND HYDROGEOLOGIC UNITS

In the multistate area covered by this study, many formation and aquifer names have been applied to parts of the carbonate rocks that together are called the Floridan aquifer system in this report. To avoid confusion and cumbersome terminology, the stratigraphic units mapped herein are time-rock units that may include all or parts of several formations. The relation between formation (rock-stratigraphic) terminology and the time-rock (chronostratigraphic) units mapped is shown on a correlation chart (pl. 2). Also delineated on this chart are the formations or parts of formations that are included in the Floridan aquifer system.

Just as it is necessary in a regional study to group several geologic formations into regionally extensive units, so must the rocks be grouped according to their general water-bearing properties. Accordingly, the Floridan aquifer system as mapped in this report represents a vertically continuous sequence of carbonate rocks that are in general highly permeable. The aquifer system is everywhere underlain by low-permeability materials that may be clastic, carbonate, or evaporite rocks. Except where the aquifer system is unconfined, it is overlain by clastic or impure carbonate rocks of low permeability.

Within the sequence of generally high permeability carbonate rocks are confining units of local to subregional extent. Over much of the study area, the subregional-scale confining units separate the Floridan aquifer system into upper and lower high-permeability zones, called the Upper and Lower Floridan aquifers, respectively. A discussion of the aquifer-confining unit terminology used in this report and companion chapters of Professional Paper 1403 is given by Johnston and Bush (1985). Locally, there may be several thin to moderately thick low-permeability units of limited areal extent within either of the high-permeability zones (for example, well FLA-FRA-7, cross section E-E', pl. 21; well GA-CHA-8, fig. 12). The amount of low-permeability rock within the aquifer system varies greatly. In the north-central part of the Florida peninsula, much of the aquifer system is highly permeable; in places in southern Florida, as much as 40 percent of the system is low-permeability rock. The confining units may consist of micritic limestone, fine-grained dolomite, or limestone and dolomite that once were permeable but whose pores are now filled with evaporite minerals; in places, the confining units may represent zones of recrystallization.

GEOLOGIC STRUCTURE

The general configuration of Coastal Plain sediments in the study area is a tilted wedge that slopes and thickens seaward from the Fall Line. Superimposed on this prism-shaped mass of sediment are gentle warps of subregional extent. Local to subregional fault systems cut all or parts of the sediment wedge in places. Some of the more prominent features that interrupt the gentle seaward slope of these Coastal Plain sediments and that have been recognized for many years are shown in figure 3. The major features shown in this figure affected Coastal Plain sediment distribution and configuration over long periods of geologic time. The large positive and negative folds in and contiguous to the Florida peninsula fall into this category. Other features, particularly some of the smaller faults shown in figure 3, were active structures for only a relatively short time, and many of them accordingly had little effect (other than local) on sedimentation.

The dominant influence on sedimentation in the study area has been the Peninsular arch, a northwest-trending feature that was continuously positive from early Mesozoic (Jurassic) until Late Cretaceous time and was intermittently positive during Cenozoic time. Southwest of and parallel to the Peninsular arch is the Ocala "uplift," which affects only rocks of middle Eocene age and younger. Although these two features are often confused in the literature, they are, in fact, distinct entities whose origins are not the same (Winston, 1976). The shape of the Peninsular arch and its effect on sedimentation in north-central Florida resemble those of an upwarp produced by compressional tectonics. Because the Ocala "uplift," does not warp or otherwise affect sediments older than middle Eocene, it is not a true uplift. This feature was produced by sedimentational processes—either an anomalous buildup of middle Eocene carbonate sediments (Win-

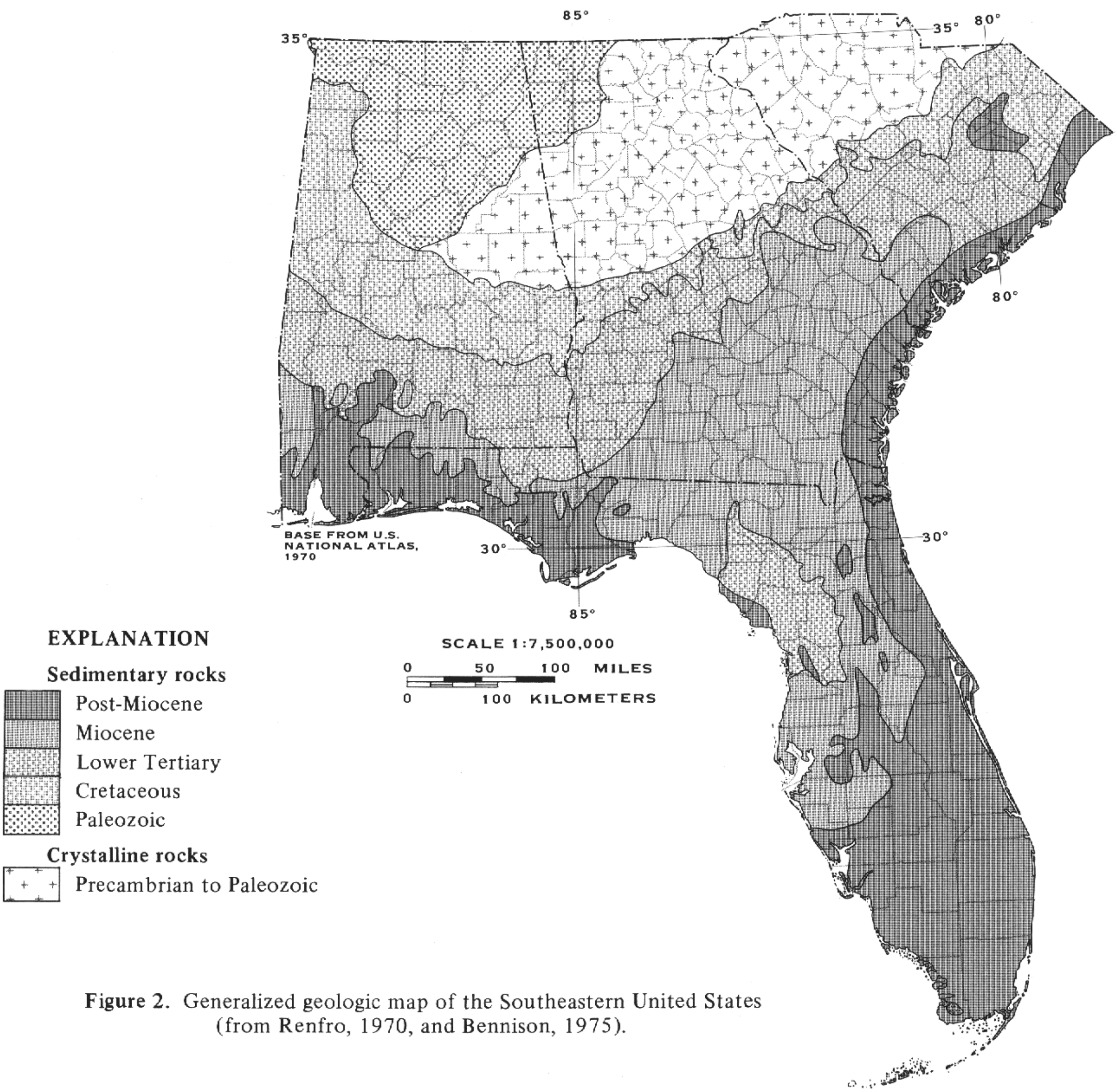

Figure 2. Generalized geologic map of the Southeastern United States (from Renfro, 1970, and Bennison, 1975).

ston, 1976) or, more likely, differential compaction of middle Eocene carbonate material shortly after deposition. Drilling on the "crest" of the Ocala "uplift" shows that the feature is not of deltaic or reefal origin.

A subtle feature that appears at first to be a structural high is located in southeastern Alabama and southwestern Georgia, roughly parallel to the Chattahoochee River. This apparent high has been called the Chattahoochee arch or anticline (Murray, 1961). At places along this feature, outcropping older rocks (Eocene) are surrounded by younger rocks (Oligocene), a situation that would seem to indicate an anticline. However, Patterson and Herrick (1971) thought that such an interpretation was incorrect. A positive structure did, in fact, exist in the general area of the "Chattahoochee arch" during Jurassic time (Miller, 1982g) but there is no evidence that it persisted beyond the end of the Jurassic. No positive feature is shown in the Chattahoochee River area on maps of the tops or thicknesses of the different time-stratigraphic and hydrologic units differentiated in this report. The "Chattahoochee arch" is considered to be an erosional feature rather than a structural one.

The Peninsular arch is flanked on three sides by negative features that have been depocenters since at least Early Cretaceous time (fig. 3). To the south, a thick sequence of platform carbonates was deposited in the South Florida basin. To the northeast, in the

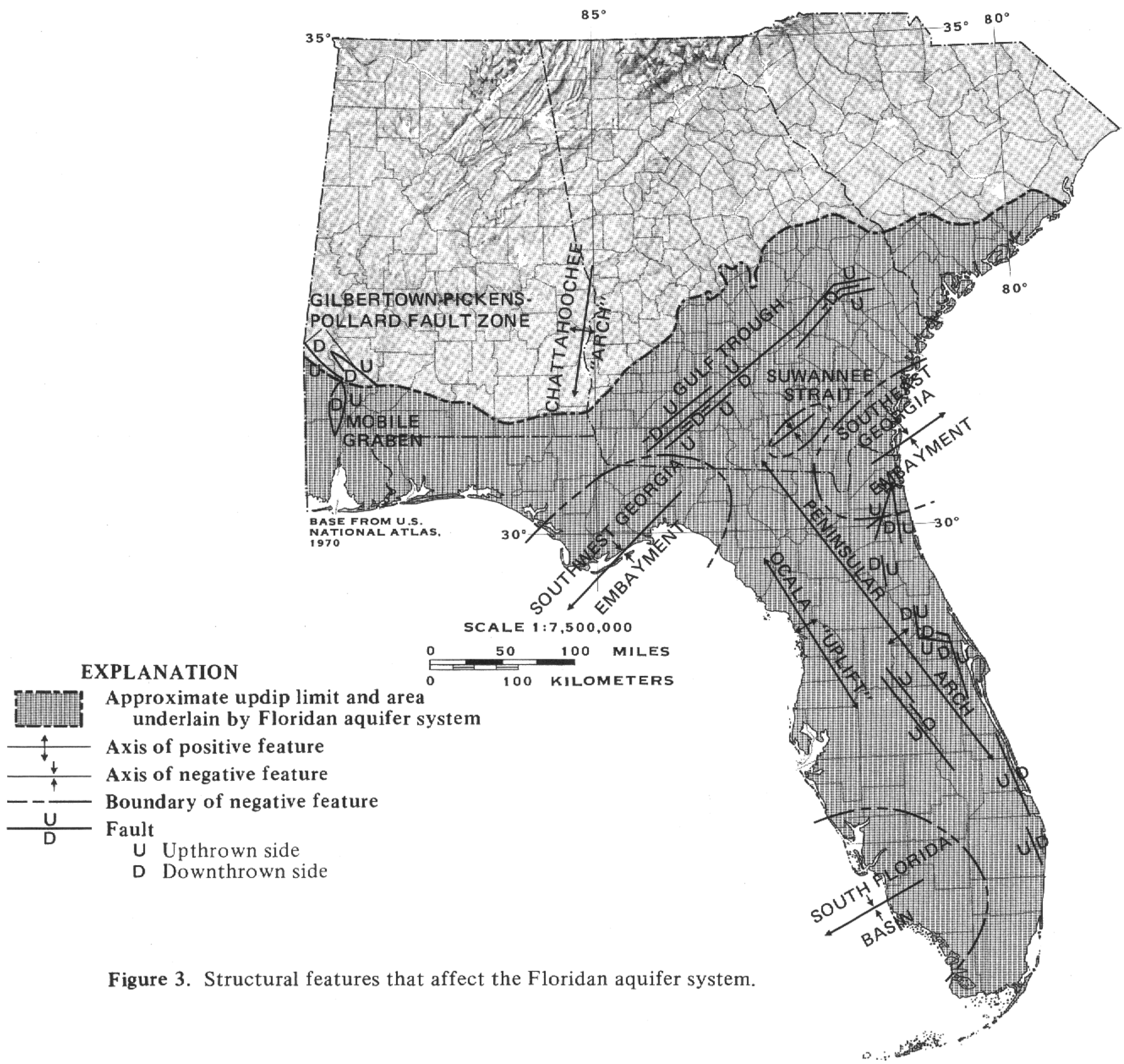

Figure 3. Structural features that affect the Floridan aquifer system.

Southeast Georgia or Savannah embayment, deposition of Lower Cretaceous clastic sediments was followed by deposition of carbonate rocks in the Late Cretaceous and early Cenozoic, which in turn was followed by deposition of Upper Cenozoic clastic rocks. The Southeast Georgia embayment represents a shallow east- to northeast-plunging syncline that subsided at a moderate rate. To the northwest of the Peninsular arch is the Apalachicola or Southwest Georgia embayment, a southwest-plunging syncline where a thick section of predominantly clastic rocks has been deposited, almost continuously, since Late Jurassic time. Rarely, in the Cenozoic, carbonate deposition spilled over westward into the Southwest Georgia embayment from the Florida carbonate platform located to the east. Farther westward, in extreme western panhandle Florida and in southern Alabama, time-stratigraphic units thicken abruptly and their tops slope steeply gulfward, reflections of the influence of the rapidly subsiding Gulf Coast geosyncline. The top and base of the Floridan aquifer system also reflect this steep gulfward slope. The limestone that comprises the Floridan, however, thins gulfward as it is replaced by fine-grained clastic rocks. This facies change continues until the limestone is absent altogether in a well about 60 mi offshore from Mobile Bay, Ala.

A negative feature in southeastern Georgia, just north of the Peninsular arch, has been called the Suwannee strait (Dall and Harris, 1892), channel (Chen, 1965), or saddle (Applin and Applin, 1967). This basin was first called a strait because it was thought to represent a channellike feature, perhaps similar to the modern Straits of Florida, that developed on the sea floor and received little sedimentation because it was swept clean by bottom currents. The feature was also thought to represent the boundary between carbonate sediments to the south and clastic sediments to the north. This carbonate-clastic boundary, however, migrates with time in a general northwest direction and is not always confined to the Suwannee strait area. Well data show a closed depression on the top of Paleocene rocks in southeastern Georgia that may be an arm of the Southeast Georgia embayment but is separated from the main body of the embayment by a sill-like ridge. The absence of such a depression in the top of rocks of lower Eocene age or younger shows that the Suwannee strait ceased to be an actively subsiding basin during the early Eocene. Accordingly, this feature had little effect on the Floridan aquifer system, although the Floridan is slightly thicker within it. Because the Suwannee strait area is a closed basin within which several stratigraphic units are anomalously thin, the exact origin of the basin is not clear. Perhaps "starved-basin" conditions during the time of deposition produced units that are thinner than what would be expected.

Several faults and fault systems are shown in figure 3. In western Alabama, north-trending arcuate faults bound the Mobile Graben, a negative feature that shows much vertical displacement (Murray, 1961). The faults to the north of the Mobile Graben are part of the Gilbertown-Pickens-Pollard fault zone, which is characterized by a series of both isolated and connected grabens. The northeast-trending series of small faults in central Georgia (fig. 3) are the boundary faults for a series of small grabens that, taken together, have been called the Gulf Trough, first described by Herrick and Vorhis (1963) and later by Gelbaum (1978) and Gelbaum and Howell (1982). Within the grabens bounded by the faults shown in figure 3, low-permeability clastic rocks have been downdropped opposite the limestone of the Floridan aquifer system and thus retard the flow of ground water within the system. Several faults shown along Florida's eastern coast (fig. 3) are of limited extent and generally show little vertical displacement. These small faults do not appear to have any effect on ground-water flow in the Floridan aquifer system.

STRATIGRAPHY

GENERAL

Because relief in the study area is generally low, outcrops of Coastal Plain strata are sparse. Accordingly, the stratigraphic units delineated herein, like the major permeability variations mapped, are based primarily on data from wells. Standard techniques of subsurface stratigraphic analysis were used to distinguish and map the separate stratigraphic units. Complex facies variations exist within all rock units throughout the study area; hence, chronostratigraphic units were mapped rather than rock-stratigraphic units. The upper and lower boundaries of the chronostratigraphic units have been made to coincide with rock-stratigraphic (lithologic) boundaries within each well used as a control point. The same rock type may not necessarily mark the boundary of the same chronostratigraphic unit from well to well, however, especially in places where facies change rapidly. Each chronostratigraphic unit may therefore encompass several different rock types. The formations or parts of formations included in the several chronostratigraphic units are shown on plate 2. The chronostratigraphic units are discussed below, from oldest to youngest. Only those units that are part of the Floridan aquifer system or its confining units are mapped